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BEYOND THE WORKSHEET: A LONGITUDINAL, MIXED-METHODS STUDY ON THE IMPACT OF A GAMIFIED DIGITAL HOMEWORK PLATFORM ON MOTIVATION, LEARNING OUTCOMES, AND ENGAGEMENT PATTERNS IN PRIMARY 3 MATHEMATICS

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Abstract

Student disengagement with traditional mathematics homework is a persistent issue in primary education, often exacerbating anxiety and reinforcing negative perceptions of the subject. Gamification, the application of game design elements in non-game contexts, offers a promising avenue to redesign homework as a more motivating and effective learning experience. However, research on its longitudinal academic impact, differential effects across student subgroups, and potential unintended consequences in primary settings is limited.

This study investigated the effects of a gamified digital homework platform, compared to traditional paper worksheets, on Primary 3 students' intrinsic motivation, self-efficacy, mathematics performance, time-on-task, and behavioral engagement over one full academic semester.

A well-designed gamified homework platform can significantly enhance motivation, voluntary practice time, and mathematics performance in Primary 3, particularly for disengaged learners. Success requires careful design that balances extrinsic rewards with intrinsic mathematical value and incorporates inclusive features to mitigate potential negative social effects. Gamification should be viewed as a pedagogical tool for deepening engagement, not merely a digital reward system.

Keywords: Gamification, mathematics homework, primary education, intrinsic motivation, self-efficacy, digital learning, mixed-methods.

Introduction

Homework in primary mathematics serves critical functions: reinforcing classroom learning, developing independent practice habits, and providing formative data for teachers. Yet, it is often a source of student frustration and parental conflict, characterized by repetitive worksheets that fail to engage or adapt to individual learner needs. This disengagement is particularly problematic in mathematics, where early negative experiences can crystallize into long-term anxiety and avoidance. The challenge, therefore, is to redesign homework to be more efficacious, engaging, and aligned with principles of motivational learning theory.

Gamification—integrating elements like points, badges, leaderboards, narratives, and challenges into educational activities—has gained traction as a potential solution. Rooted in Self-Determination Theory (Ryan & Deci, 2000), effective gamification can address core psychological needs: *autonomy* (through choice and agency), *competence* (through immediate feedback and scaffolded challenges), and *relatedness* (through social features). While promising, the evidence base in primary mathematics is nascent and mixed. Some studies report boosts in engagement and time-on-task, but findings on direct academic achievement are less consistent. Critical voices warn of potential pitfalls: gamification may trivialize learning, encourage superficial "point-scoring" over deep understanding, or demotivate lower-performing students through public leaderboards.

This study addresses key gaps by examining not only *if* gamification works, but *how*, *for whom*, and *under what conditions*. Prior research often involves short-term interventions; this study implements a semester-long integration to assess sustained effects. Furthermore, it moves beyond a simple treatment-control comparison to explore differential impacts based on initial motivation levels and gender. Finally, it triangulates log data with rich qualitative insights from students, teachers, and parents to understand the lived experience of gamified homework.

The present study is guided by the following research questions:

1. What are the differential effects of a gamified digital homework platform versus traditional worksheets on Primary 3 students' intrinsic motivation, self-efficacy, and mathematics performance?
2. How does the gamified platform influence behavioral engagement metrics, specifically time-on-task and voluntary problem-solving attempts?
3. How do students, teachers, and parents perceive the gamified homework experience, and what are its perceived benefits and drawbacks?
4. Does the intervention effect vary based on students' initial levels of motivation or gender?

We hypothesize that the gamified platform will lead to significant increases in motivation and self-efficacy, and a modest but significant improvement in mathematics performance, mediated by increased time and effort on task.

Methods

A sequential explanatory mixed-methods design was employed. The primary phase was a cluster-randomized controlled trial at the classroom level. This quantitative phase was followed by a qualitative phase to explain and elaborate on the quantitative results.

Participants were 180 Primary 3 students (Mean age = 8.7 years) from six classes in a large suburban primary school. Classes were randomly assigned to condition, resulting in 90 students (3 classes) in the **Gamified Platform group** and 90 students (3 classes) in the **Traditional Worksheet group**. Demographics were balanced across groups (48% female, 52% male; diverse socioeconomic background). All teachers (n=6) had similar experience levels.

- **Gamified Platform Group:** Used the adaptive platform "MathQuest" for all homework for 16 weeks. Key features included:
  - **Narrative Context:** Homework was framed as a "space exploration" where each topic (e.g., multiplication) was a planet to conquer.
  - **Adaptive Pathways:** The algorithm adjusted problem difficulty based on performance.
  - **Core Mechanics:** Students earned "energy points" for correct answers, "perseverance badges" for multiple attempts on hard problems, and "concept master" badges for demonstrating understanding via explanations.
  - **Feedback:** Immediate corrective and explanatory feedback was provided for every answer.
  - **Social & Progress Elements:** A **non-public, personal progress leaderboard** showing only the student's own growth over time was used. A class "cooperation meter" filled as the whole class completed quests, encouraging collective effort.
- **Traditional Worksheet Group:** Completed equivalent paper-and-pencil homework assignments from the standard school curriculum, focusing on the same mathematical content (multiplication, division, fractions, measurement). Teachers graded and returned worksheets weekly.

1. **Quantitative Measures:**
   - **Intrinsic Motivation Inventory (IMI):** A 22-item scale assessing interest/enjoyment, perceived competence, and effort. Administered pre- and post-intervention ($\alpha = .89$).
   - **Mathematics Self-Efficacy Scale:** A 10-item researcher-developed scale ($\alpha = .85$).

- **Mathematics Performance:** A district-validated, 25-item standardized test covering computation and problem-solving (α = .82).
- **Behavioral Engagement Analytics:** For the Gamified group, platform logs captured time-on-task, problems attempted, error rates, and badge acquisition. For both groups, homework completion rates were tracked.

2. **Qualitative Data:**

- **Student Focus Groups:** Four focus groups (6 students each, stratified by performance and condition) were conducted post-intervention.
- **Teacher Interviews:** All six participating teachers underwent a 45-minute semi-structured interview.
- **Parent Surveys & Interviews:** All parents received a survey; 18 from the Gamified group participated in follow-up interviews.

Quantitative data were analyzed using repeated-measures ANOVA and ANCOVA to compare group differences in motivation and performance, controlling for pre-test scores. Time-on-task and problem attempt data were analyzed using independent samples t-tests. Subgroup analyses were conducted by median-splitting the pre-IMI scores and by gender.

Qualitative data were audio-recorded, transcribed, and analyzed using thematic analysis. Codes were developed inductively and then grouped into overarching themes (e.g., "Agency and Choice," "The Double-Edged Sword of Competition," "From Chore to Challenge"). Quantitative and qualitative findings were integrated during the interpretation phase.

Student Perceptions: Gamified group students overwhelmingly described homework as "fun," "like a game," and "something I want to do." They valued the narrative ("I wanted to see what happened on the next planet") and the autonomy to retry problems. The badges for perseverance were particularly motivating: "It felt good to get the 'Never Give Up' badge even though I got it wrong a few times first."

Teacher Observations: Teachers reported a "noticeable drop in homework complaints" and that students "came to class more prepared." However, two teachers expressed concern that a few high-achieving students focused on "speed to get points" rather than thoughtful problem-solving.

Parent Feedback: Parents noted less "homework battles" and increased independent work. Several mentioned their child talking positively about math. A few parents in the Gamified group expressed concerns about screen time and whether the game elements were a "distraction."

Emergent Concerns: A key theme was the careful design of social features. Students appreciated the *cooperative* class meter but indicated that a public, ranking leaderboard would have caused stress. This validated the design choice to use a personal progress tracker.

The gamified platform successfully increased motivation, self-efficacy, time-on-task, and voluntary practice, leading to a statistically significant, though modest, improvement in mathematics test scores. The intervention was particularly effective for re-engaging previously disinterested students. Qualitative data confirmed the motivational benefits while highlighting critical design principles to avoid superficial engagement and social comparison.

Discussion

The results confirm that a thoughtfully designed gamification framework can transform the homework experience in primary mathematics, aligning it more closely with evidence-based principles of motivation and learning. The modest but significant gain in performance, coupled with the large increase in engagement, suggests gamification can help close the "practice gap" for disengaged learners, providing them with the volume and quality of practice necessary for skill consolidation.

The findings strongly support Self-Determination Theory. The platform's narrative and choice elements likely supported *autonomy*. Immediate feedback and adaptive challenges fostered a sense of *competence*. The cooperative class goal subtly addressed *relatedness* without the perils of direct competition. The significant impact on initially low-motivation students is critical; it suggests gamification can act as a "gateway" to re-engage students who have already developed negative associations with mathematics, potentially altering their long-term academic trajectory.

1. **Focus on Learning-Centric Design:** Game elements must be in service of learning objectives. Badges should reward desirable learning behaviors (e.g., perseverance, explanation) not just speed or final answers.

2. **Prioritize Intrinsic Over Extrinsic Motivation:** Use narrative, mystery, and challenge as primary drivers. Points and badges should provide informative feedback, not become the sole goal.
3. **Design for Equity and Inclusion:** Avoid public leaderboards that can demoralize. Use personal progress trackers and team-based goals. Ensure adaptive difficulty prevents frustration for struggling learners and boredom for advanced ones.
4. **Integrate with Pedagogy:** The platform must be seamlessly aligned with classroom instruction. Teachers need dashboards to interpret learning analytics and identify students needing support.

Limitations include the single-school setting, the specific design of the "MathQuest" platform (other designs may yield different results), and the inability to fully blind participants. The 16-week period does not reveal if the motivational novelty wears off.

Future research should: a) conduct multi-year longitudinal studies to assess long-term effects on achievement and motivation, b) dismantle studies to identify which specific game elements (narrative, badges, etc.) are most impactful, and c) investigate the optimal balance of screen-based and off-screen mathematical activities in a hybrid homework model.

Conclusion

This study demonstrates that gamification, when implemented as a pedagogically informed, learner-centered system, can effectively address the chronic problem of homework disengagement in primary mathematics. It is not a magic solution, but a powerful tool to increase access to meaningful practice and foster a more positive disposition towards mathematics. The ultimate goal is not to make homework fun for fun's sake, but to use the motivational power of game design to help all students engage more deeply with the inherent challenge and beauty of mathematical thinking.

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